(IJPS) 2026, Vol. No. 21, Special Issue 2 **e-ISSN: 2455-6270 p-ISSN: 2455-7455**

Harnessing Biotech for a Viksit Bharat: Strategies and Challenges Ahead in Agriculture

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DOI:10.37648/ijps.v21i02.020

[1]*Received: 30/11/2025; Accepted: 31/12/2025; Published: 07/01/2026*

Abstract

India's vision of Viksit Bharat by 2047 envisions a developed nation where agriculture plays a pivotal role in achieving self-reliance, sustainability, and economic growth. With agriculture employing over 54% of the workforce and contributing approximately 18% to the Gross Value Added (GVA), biotechnology emerges as a transformative force to address persistent challenges like low productivity, climate vulnerability, and resource scarcity. This article explores the current state of Indian agriculture, key biotechnological applications such as genetically modified (GM) crops and genome editing, strategic initiatives aligned with national policies like BioE3 (formally known as the Biotechnology for Economy, Environment, and Employment Policy), and formidable challenges including regulatory hurdles and socio-economic barriers. Drawing on case studies of Bt cotton and emerging bio-manufacturing hubs, it highlights successes and pathways forward. Future prospects indicate that leveraging biotech could triple agricultural output to $3.1 trillion by 2047, but requires balanced innovation, inclusive adoption, and robust governance. By integrating biotech with traditional farming, India can foster resilient agri-food systems, enhance farmer incomes, and secure nutrition for 1.4 billion people. This review underscores the need for policy reforms to harness biotech's potential while mitigating risks, paving the way for a sustainable Viksit Bharat by 2047.

Keywords: *Biotechnology; Vikasit Bharat; Indian agriculture; GM crops; sustainable farming; regulatory challenges*

1. Introduction

The clarion call for Viksit Bharat—India's ambitious blueprint to become a developed nation by 2047—places agriculture at the heart of its transformative agenda. Envisioned by Prime Minister Narendra Modi, this vision emphasizes self-reliance (Atmanirbhar Bharat), sustainable development, and equitable growth, with agriculture as the bedrock supporting rural economies and food security. As India grapples with a projected population of 1.6 billion by mid-century, the sector must evolve to feed its people while combating climate change, water scarcity, and soil degradation. Biotechnology, encompassing genetic engineering, tissue culture, and bio-fertilizers, offers revolutionary tools to boost yields, enhance resilience, and minimize environmental footprints.

Yet, India's agricultural landscape remains fragmented: smallholder farms dominate (86% under 2 hectares), productivity lags global averages, and post-harvest losses exceed 20%. The sector's GVA grew to ₹1,502 thousand crore in 2023-24, reflecting a 225% increase over decades, but growth is uneven, with 2024-25 estimates at 3.8%.

[1]*How to cite the article:* Purushotham G (2026); Harnessing Biotech for a Viksit Bharat: Strategies and Challenges Ahead in Agriculture; *International Journal of Professional Studies*; Vol 21, Special Issue 2, 143-147; DOI: http://doi.org/10.37648/ijps.v21i02.020

Presented in National Seminar on "Vikasit Bharat @ 2047: The Strategies and Challenges" on 8-9, January 2026, Nagarjuna Govt. College (A), Nalgonda, Telangana.

Biotech interventions, from Bt cotton's pest resistance to CRISPR-edited rice, have shown promise, yet adoption is stymied by regulatory delays and public skepticism. This article delineates strategies to integrate biotech into Viksit Bharat's agricultural framework, analyzes challenges, and charts prospects, grounded in empirical data and policy insights. By 2047, biotech could propel the sector to $1.8-3.1 trillion, but only through concerted action.

2. Review of Literature

- **Biotechnology in Indian Agriculture – Need for a Balanced Innovation**

by V. Basil Hans. Publisher-NL Journal of Agriculture and Biotechnology: This article explores the role of biotechnology in Indian agriculture, focusing on its practical applications, economic contributions, and environmental effects.

- **Regulatory Challenges Slow India's Progress on GM Crop Adoption**

Published in **Biotech Updates**, June 11 2025. By Dr. Rohini Sreevathsa, Principal Scientist at the Indian Council of Agricultural Research - National Institute for Plant Biotechnology (ICAR-NIPB), New Delhi, stated that India's scientific community is making notable strides in developing Genetically Modified (GM) traits for staple crops. However, the absence of a clear and transparent regulatory framework continues to hinder progress.

- **Vikasit Bharat @2047: Pathway to Sustainable Agriculture Development in India**

by Mohd Hamid, Published in SSRN, Nov- 7- 2024 :This study examines the contribution of sustainable agriculture to realizing the vision of "Viksit Bharat," emphasizing the integration of advanced technologies into farming practices, including precision agriculture.

3. Objectives

- To explore the potential and opportunities of biotechnology in enhancing Indian agriculture.
- To investigate the challenges and limitations of implementing biotechnology in Indian agriculture

4. Methodology

This study employs a conceptual and qualitative research methodology to investigate the opportunities and challenges of biotechnology in Indian agriculture. By synthesizing data from credible secondary sources, including the National Mission for Sustainable Agriculture (NMSA), the Ministry of Environment, Forest and Climate Change, the Department of Biotechnology, the Ministry of Agriculture, as well as case studies and peer-reviewed journals, this article provides a comprehensive understanding of the current state of biotechnology in Indian agriculture, its potential benefits, and the obstacles hindering its widespread adoption.

- **Current Status of Indian Agriculture**

India's agriculture sector is a paradox of potential and peril. Spanning 59% of arable land, it sustains 54.6% of the workforce and contributes 17.7-18.4% to GVA as of 2023-24. Gross production value is projected at US$507.74 billion in 2025, with a CAGR of 6.61% through 2029. Key crops like wheat (113.292 million tons in 2025), rice, and millets underpin food security, yet yields remain 50% below global benchmarks due to fragmented landholdings and monsoon dependency.

Climate impacts exacerbate vulnerabilities: erratic rainfall affected 2024 kharif sowing, while heatwaves reduced wheat output by 5%. The sector's value reached INR 99,689 billion in 2024, eyeing INR 236,603 billion by 2033 at 10.08% CAGR, driven by exports and tech integration. However, small farmers—comprising 86% of holdings—face debt traps, with average incomes at ₹10,218 annually, far below urban wages.

Digital adoption is rising: by 2025, 60% of farmers use mobile apps for market access, boosting efficiency by 20% via data-driven decisions. Initiatives like PM-KISAN (₹6,000 annual support) and e-NAM(e-National Agriculture Market) have disbursed ₹2.8 lakh crore to 11 crore farmers since 2019. Yet, challenges persist: 40% of produce rots in supply chains, and groundwater depletion threatens 60% of irrigated areas. In Viksit Bharat's context, agriculture must shift from subsistence to high-value, sustainable models, where biotech plays a catalytic role.

This data underscores the urgency for innovation. Biotech, with its precision tools, can bridge gaps in productivity and resilience, aligning with Viksit Bharat's sustainable growth imperatives.

- **Applications of Biotechnology in Indian Agriculture**

Biotechnology's toolkit—ranging from marker-assisted breeding to synthetic biology—has reshaped global agriculture, and India is no exception. In food and agriculture, biotech enhances yields by 20-30%, reduces pesticide use by 37%, and bolsters pest resistance. Applications span GM crops, bio-fertilizers, and tissue culture, addressing India's diverse agro-climatic zones.

GM crops dominate: Bt cotton, introduced in 2002, covers 95% of cotton acreage, yielding 50-60% higher outputs and slashing insecticide sprays by 50%. As of 2025, GM area dipped 7.1% due to regulatory flux, but innovations like GM mustard (DMH-11) await commercialization for oilseed self-sufficiency. Genome editing via CRISPR-Cas9,(Clustered Regularly Interspaced Short Palindromic Repeats). It is a revolutionary gene-editing technology derived from a bacterial immune system, enabling precise modifications to DNA for applications in agriculture, medicine, and biotechnology. In the context of the BioE3 Policy and Indian agriculture, CRISPR is used to develop climate-resilient crops, such as drought-tolerant rice and blast-resistant basmati, enhancing yields and sustainability.

Micropropagation via tissue culture has produced 14 improved varieties of rice, wheat, and maize, reaching farmers and enhancing nutritional profiles. Bio-fertilizers, like rhizobium inoculants, fix nitrogen for legumes, reducing chemical fertilizer dependency by 25% and cutting costs for smallholders. In animal husbandry, biotech clones elite breeds and develops vaccines, though nascent. Urban agriculture benefits from hydroponic biotech, integrating genome editing for nutrient-dense greens.

Recent trends include RNA interference (RNAi) for pest control and synthetic microbes for soil remediation, promising 15% annual growth in biotech seeds. Synergies with natural farming amplify sustainability, as biotech optimizes microbial consortia for organic yields. In Viksit Bharat, these applications can elevate exports, targeting Uttar Pradesh's goal to lead global agri-exports by 2030.

- **Strategies for Harnessing Biotech in Indian Agriculture**

To realize Viksit Bharat, India must adopt multifaceted strategies blending policy, R&D, and extension services. The BioE3Policy (2024) spearheads this, aiming to double the $151 billion bioeconomy to $300 billion by 2030 through bio-manufacturing and green tech. It fosters hubs like BRIC-National Agri-Food Biomanufacturing Institute in Mohali, promoting self-reliance and jobs.

Policy levers include the Viksit Krishi Sankalp Abhiyan, modernizing farming via biotech dissemination. R&D investments via DBT(Department of Biotechnology) and ICAR(Indian Council of Agriculture Research) target climate-resilient varieties, with ₹5,000 crore allocated for genome sequencing. Public-Private Partnerships (PPPs)

accelerate commercialization, as seen in ICFA's(Indian Council of Food and Agriculture) Earth Day collaborations for input efficiency.

Farmer-centric approaches emphasize training: 10 million farmers to adopt biotech by 2030 via KVKs (Krishi Vignyan Kendras)and digital platforms. Export strategies leverage biotech for high-value crops, aligning with UP's 2047 goals. Integrating AI and drones with biotech enhances precision farming, potentially adding $95 billion to incomes. The New Deal for Agriculture proposes holistic reforms, merging biotech with MSP enhancements. These strategies position biotech as a Viksit Bharat enabler, fostering inclusive growth.

5. Challenges in Adopting Biotechnology

Despite promise, biotech adoption faces multifaceted hurdles. Regulatory bottlenecks loom large: The GEAC's (Genetic Engineering Appraisal Committee)protracted approvals delayed GM mustard for years, with Supreme Court interventions in 2025 urging policy clarity. Only Bt cotton is commercialized; food GM crops encounter moratoriums amid biodiversity concerns. Public perception fueled by anti-GMO activism, views biotech as "Frankenfoods" eroding trust despite safety data.

Socio-economic barriers include small farm sizes, limiting economies of scale, and high seed costs (20-30% premium for biotech varieties). Intellectual property issues deter local innovation, with 80% of biotech patents foreign-held. Infrastructure gaps—cold chains, labs—hinder R&D, while funding lags at 0.5% of agric-GDP versus global 2%. Climate and ethical dilemmas, like gene flow risks, compound challenges for developing nations. Trade pressures, as in US-India talks pushing GM imports, highlight geopolitical tensions. Addressing these demands agile governance, education campaigns, and inclusive policies to prevent a digital-a grid vide.

Case Studies: Successes in Biotech Adoption

Bt cotton exemplifies biotech triumph: Since 2002, it boosted yields by 150% and farmer incomes by ₹10,000/ha, covering 11.6 million ha in 2024 despite a 7.1% dip. In Maharashtra, adoption reduced suicides by stabilizing incomes, as per Indian Council for Research on International Economic Relations (ICRIER) studies.

Bio Prime’s microbial consortia, via TAAS (Trust for Advancement of Agricultural Sciences) collaboration, enhanced sugarcane yields by 25% for 50,000 farmers, cutting inputs by 30%. In Punjab, CRISPR-edited basmati rice resists blasts, piloted on 1,000 ha with 20% yield gains. The $1 billion biotech sector, as per DBT, spawned firms like Rasi Seeds, exporting bio-inputs.

These cases, yielding 30% projected increases by 2025, underscore scalable models for Viksit Bharat.

6. Future Prospects: Biotech Towards 2047

By 2047, biotech could triple agric-output to $3.1 trillion, with bioeconomy hitting $1 trillion. Food demand rises 2.44% annually, necessitating 30% yield hikes via gene-edited staples. Circular economy integrations, like bioenergy from waste, align with net-zero goals.

NAAS’s (National Academy of Agricultural Sciences) 2047 roadmap envisions biotech-centric education and extension, fostering 25-35% income growth. Challenges like equity must yield to inclusive innovations, ensuring Viksit Bharat's green revolution 2.0.

7. Conclusion

As India advances toward the Viksit Bharat vision by 2047, biotechnology stands as a pivotal driver of economic transformation in agriculture, with the potential to contribute $3.1 trillion to the economy. By scaling innovations like Bt cotton, GM mustard, and biofortified crops, biotechnology can boost agricultural productivity by 20-30%, enhancing farmer incomes and contributing to rural GDP growth. The BioE3 policy's focus on biotechnology-driven startups and research hubs is poised to generate millions of jobs, fostering a $200 billion bioeconomy while strengthening India's position in global agricultural markets, with exports projected to grow beyond $50.2 billion annually. Cost efficiencies from biofertilizers and biopesticides, coupled with reduced losses from climate-resilient crops, could save farmers billions annually, stabilizing rural economies. However, realizing this potential demands overcoming economic barriers through streamlined regulations, affordable biotech inputs, and robust market linkages. Investments in rural infrastructure, digital platforms, and skill development will further amplify economic returns, ensuring equitable benefits for smallholder farmers. By integrating ethical governance and sustainable practices, biotechnology can sow the seeds of a prosperous, inclusive, and resilient Bharat, driving sustained economic growth and global competitiveness by 2047.

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